

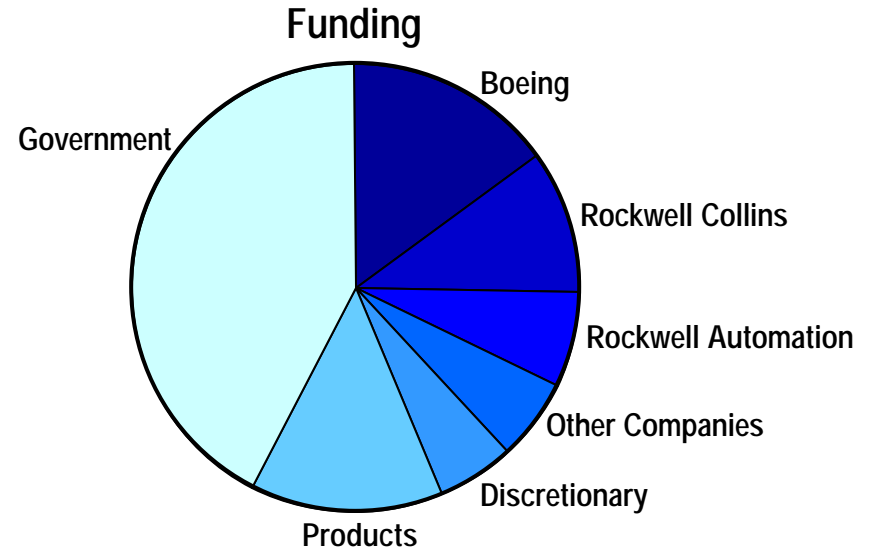
Wireless Sensor Networks: Sensing, Processing, & Visualization

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NDIA, New Orleans
March 14, 2002

Rockwell Scientific Company (RSC)

- Independent, privately held
- Formerly Rockwell Science Center
- 480 full time staff, 150 Ph.D's
- Multi-disciplined high tech enterprise
 - Contract R&D:
 - Government and commercial
 - Non-captive
 - Commercialization:
 - Product sales, licensing and spin-offs



Thousand Oaks
R&D & Prototyping - Since 1962 ('64)

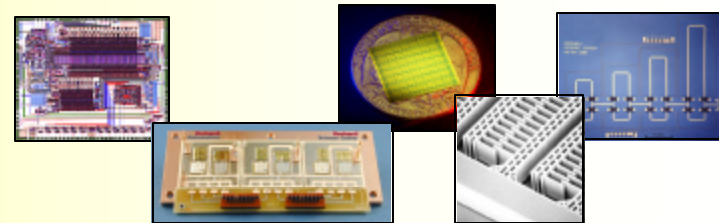


Camarillo
R&D & Manufacturing - Completion 2001

Core Technologies

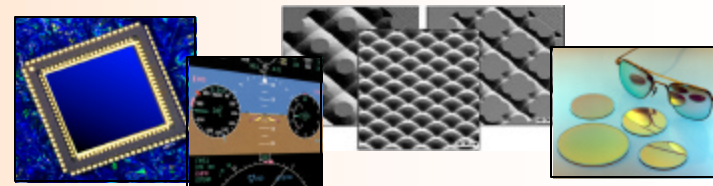
• Electronics

- High Speed Mixed Signal Devices, IC's and Fabrication
- Millimeter Wave Electronics and Antenna Technology
- MicroElectroMechanical Systems (MEMS)
- Power Electronics and Sub-systems



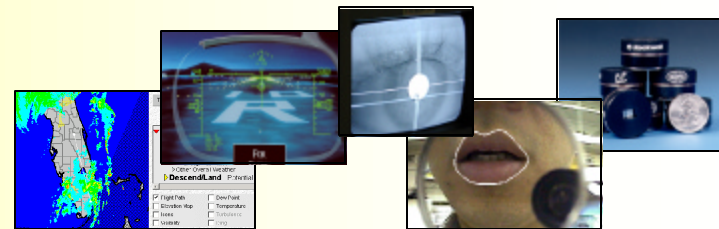
• Imaging and Optics

- Electronic Imaging Sensors - Infrared and Visible
- Display Technology
- Optical coatings and micro-optics



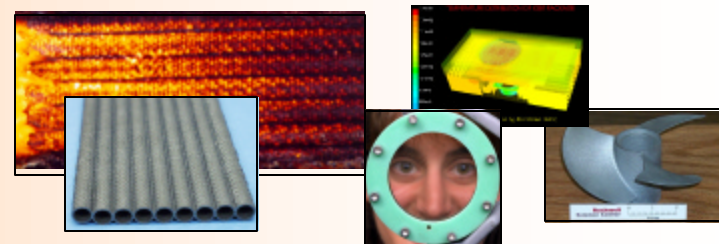
• Information

- Wireless Systems / Integrated Sensor Networking
- Diagnostic Algorithms
- Visualization & Interaction Systems
- Design Tools and Software Process
- Situation Awareness and Intelligent Decision Making



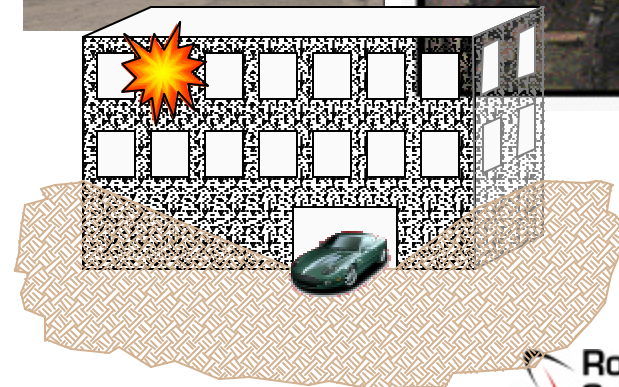
• Materials & Computation

- Structural Materials
- Engineered Materials and Coatings
- Sensors and Actuators
- Packaging and Thermal Management
- Computation and Simulation



Wireless Integrated Networked Sensors (WINS)

- Security & Force Protection
 - mounted, dismounted, chem/bio threats
 - Assessment & Controlled Response
- Intelligence, Surveillance, Reconnaissance
 - land, sea, underground monitoring and situational awareness
- Operational Performance Enhancement
 - better information provides means to achieve better performance at all levels from battle force individual
- Logistics Management
 - machine health and performance prediction
 - inventory and asset status and location
 - personnel monitoring
- Minefield Replacement / Safing - bring C3I to area denial
- Real-time Bomb Damage Assessment
- Targeting



Wireless Integrated Networked Sensors (WINS)

- **Network**

- Multi-hop
- Self-healing
- Self-organizing
- Dynamically Reconfigurable
- Random Topology

- **Multiple sensor input**

- **Data processing on node**

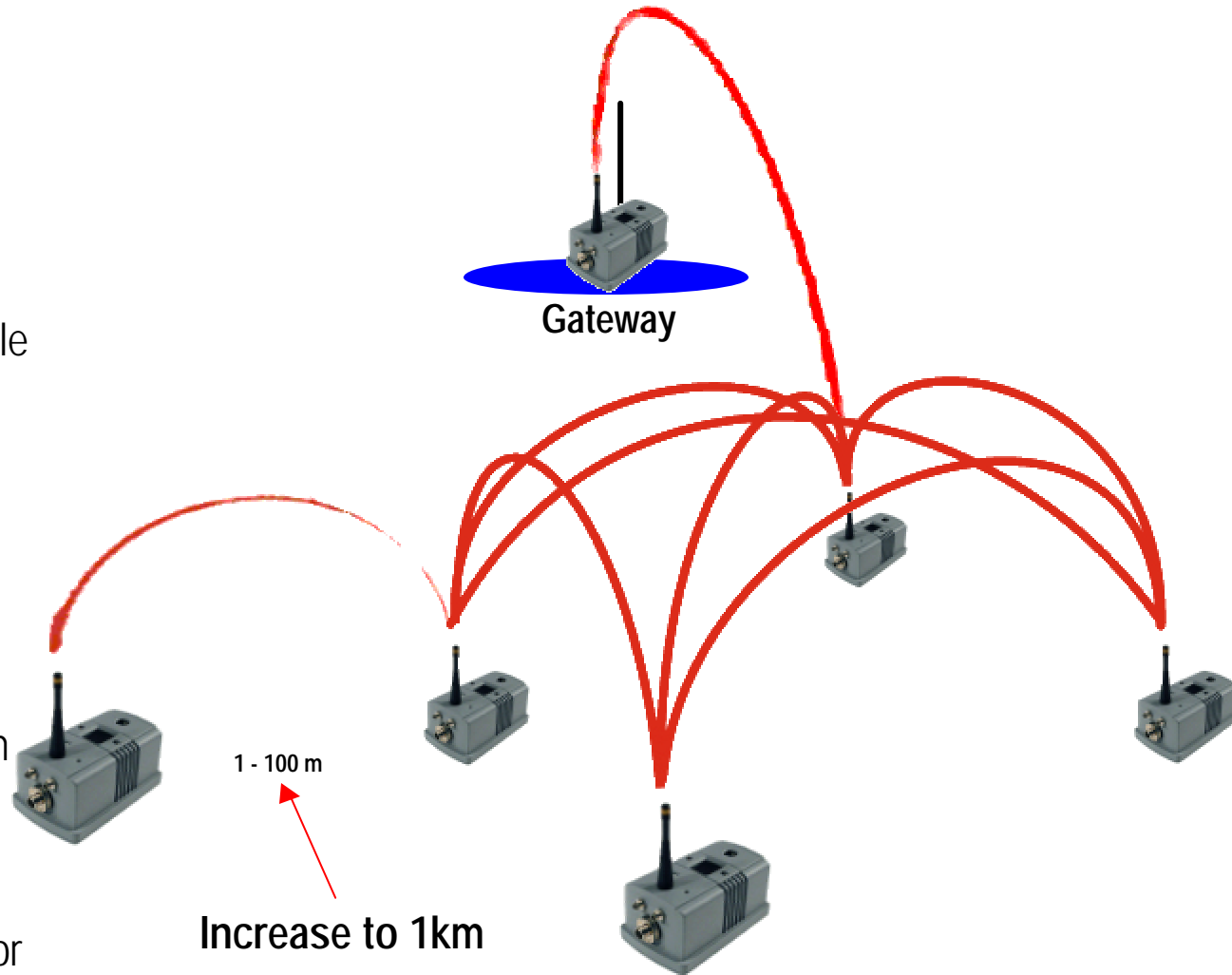
- Condition Monitoring

- **Nodes transmit and receive**

- 900 Mhz Spread Spectrum
- Other Radios Possible

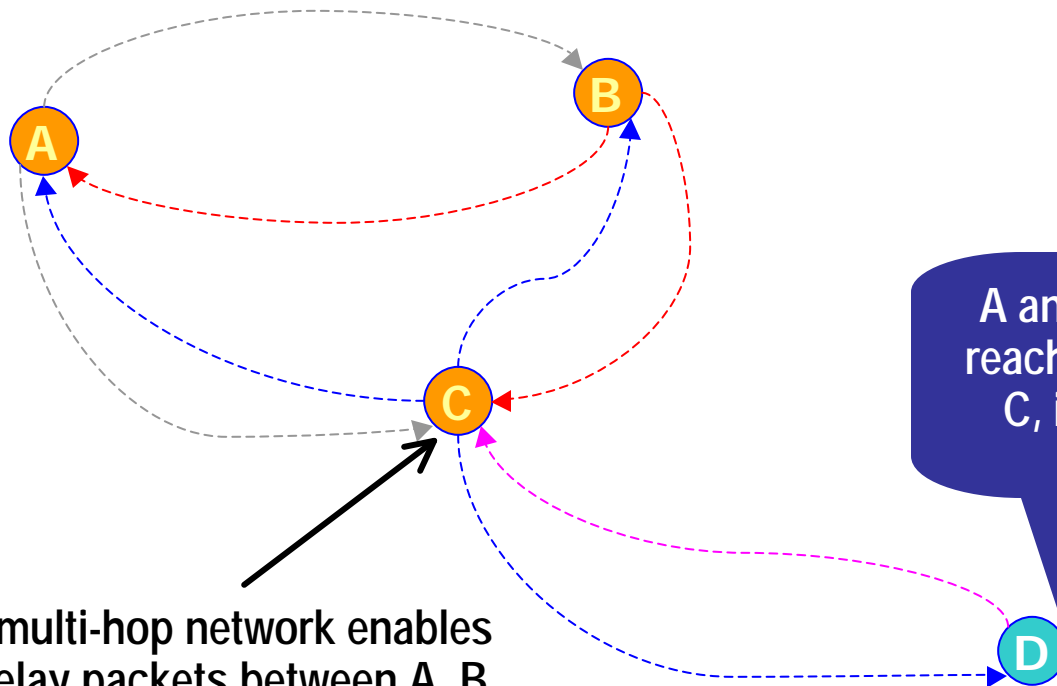
- **Mobile Agents**

- Discovery routines allow for mobile agents to access data at any time



RSC Multi-Hop Protocol

“Traditional” point-to-point ad-hoc network (such as 802.11b)



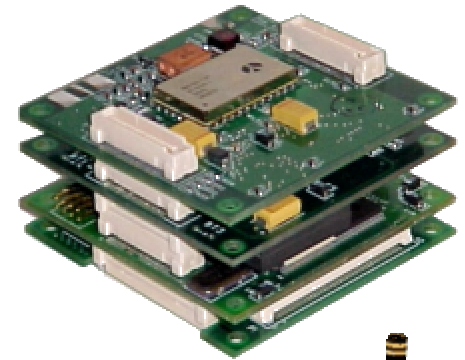
A and B are out of D's direct reach. Although D can talk to C, it has no link to A or B.

RSC WINS multi-hop network enables node C to relay packets between A, B, and D.

Communication between A, B, and D becomes possible!

Modular (Stacked) Node Design

- Processor Board
 - StrongARM 1100 CPU
 - 4MB Flash, 1MB SRAM (expandable)
 - External RS-232, USB, SPI, SDLC interfaces
 - uC/OS, eCos, and vxWorks RTOS support
- Sensor Board
 - 5 analog sensor inputs, up to 60kHz sampling rate
 - Input signal amplification and filtering
 - 3-5V output power for external sensor circuitry
- Communication (Radio) Module
 - Direct Sequence Spread Spectrum (900MHz)
 - Adaptive transmit power, up to 100m range
 - 100kbps over-the-air data rate
 - 8-bit onboard CPU to support various MAC protocols
- Power Supply Board



Software Layout

- System is based on 3 OS tasks:
 - Data-packet Dispatcher
 - Network Support
 - Application thread
- Interrupt-driven routines:
 - UART (serial IO) Driver
 - High-rate Data Sampling
 - OS Support (time source)

RTOS (uC/OS)	Application			
	Signal Processing	Data Acquisition	Networking	Debugging & Monitoring
* Multitasking * Scheduling * Queues * Semaphores * OS Timers	Math and Signal processing libraries	* Multichannel ADC * Gain control * Analog filters * Digital IO's * High freq sampling	* Net Mgmt * Routing Protocols * Link Layer * MAC	* Local Node * Remote (network channel)
Monitor	Hardware Abstraction Layer (HAL)			
* System Init * SW Update * Low Level Debug	* Memory Mgmt * Non-volatile Memory * Power Mgmt	* GPIO's (+ LED) * IO's (UART's, SPI, USB) * Timers		
WINS Hardware				

Sensors

- Acceleration
- Temperature
- Pressure
- Acoustic
- Digital Imaging
- Magnetometer
- Other...

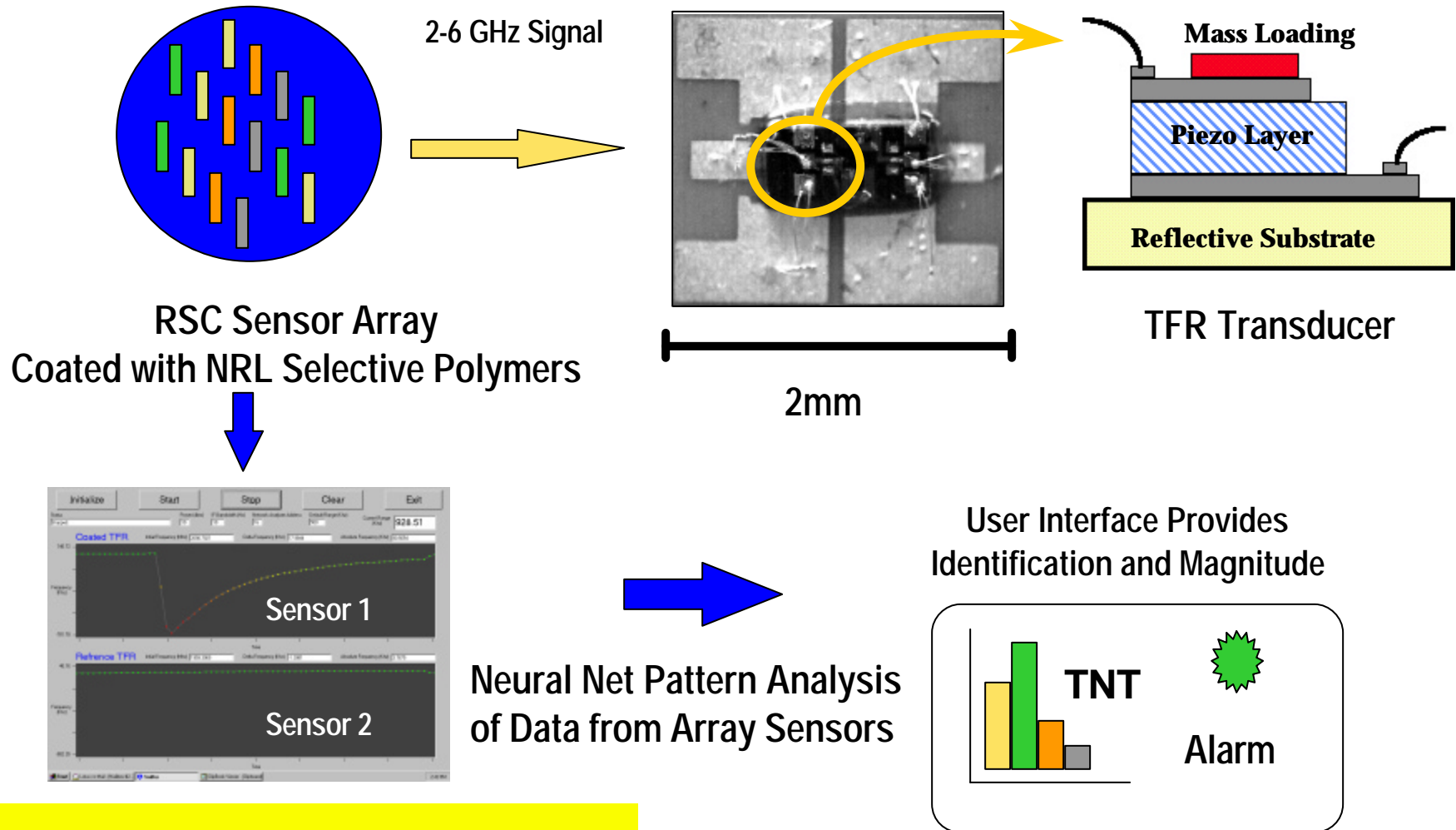


Endevco - Temperature/Accelerometer
model 55M7



Prototype WINS Imaging Sensor
based on RSC CMOS Camera

Chem/Bio Sensor Possibilities: RSC DARPA "Dog Nose"



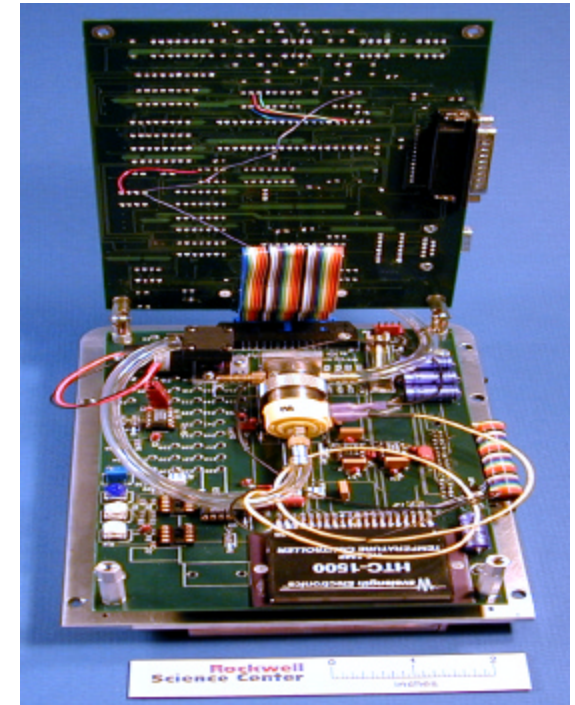
Applications

Mine Detection
Solvent Spills

Chemical Warfare Agents
Food Spoilage

Chem/Bio Sensor Possibilities: RSC DARPA "Dog Nose"

- Current system shows ability to detect DNT/DNB/TNT at the low ppb level in 2 second time frame.
- Improvement required in TFR surface layer to avoid water interference effects.
- Field prototype electronics have been fabricated.
- Program no-cost extension in place to address sensitivity/interference issues.
- Path to fully miniaturized system defined



Chem/Bio Sensor Possibilities

Biological Sensors:

- Lincoln Labs & BAWS: BIO Agent Warning Sensor
 - Automatic & rapid detection (10s of sec.); low concentration clouds (10-100/liter).
 - Non BIO agent specific; now in production – 1000 units.
- CANARY B – Cell Eng. & Sensor Development. speed & sensitivity for pathogen- identification in 10's of seconds using DNA analysis. Success may come in ~ 5 yrs. (DARPA \$)

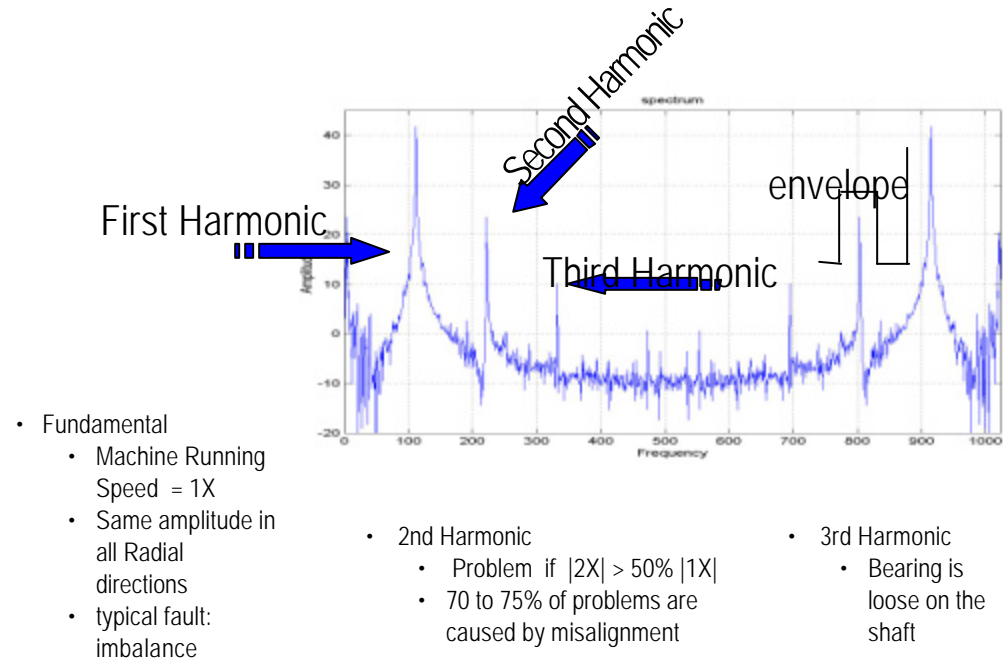
Sensors – Point – In the Web Provide a 2D or 3D 'Picture' of Any Agent Cloud Moving Toward The Base or Key Facility

System Enhancement (short term)

- Communication range increase (up to 1km) by developing a new RF-amplifier (up to 1W transmit power)
- Efficient power management (targeted 1 week node lifetime)
 - Novel node hardware (CPU core voltage control, boards shut-down)
 - More efficient node-level power management algorithms
 - Power aware distributed data processing and networking support
- Use of directional antennae (improved LPI/LPD, AJ, and communication range)
- Alternative wireless solutions: novel Rockwell modem / RF chipsets, 802.11(a,b,g) COTS parts, custom modem design with reliable, low power, agile waveforms and controls
- Node miniaturization through higher level of hardware integration (by using new processors and wireless com chipsets)

Nodes Execute Algorithms

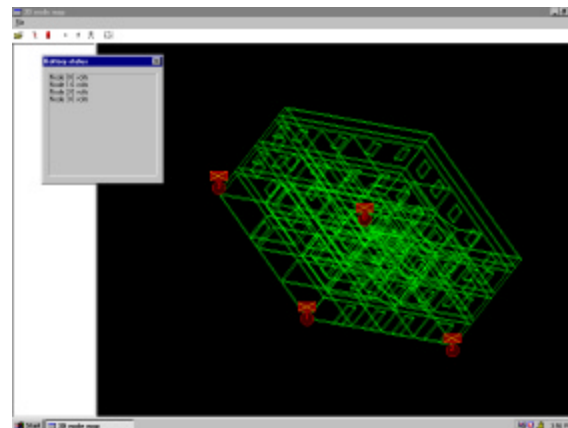
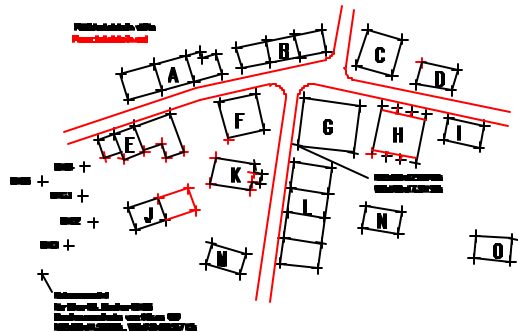
- Extensive experience in Diagnostics and Condition- Based Monitoring
 - Thresholding of average sensor values
 - Comparison with past values and slope determination (trending)
 - Spectral analysis of vibration data
 - Machine fault identification and prediction
 - Bearing Failure
 - Pump Cavitation
- Some testing of algorithms for personnel, vehicle detection
- Future developments will center more on antiterrorism



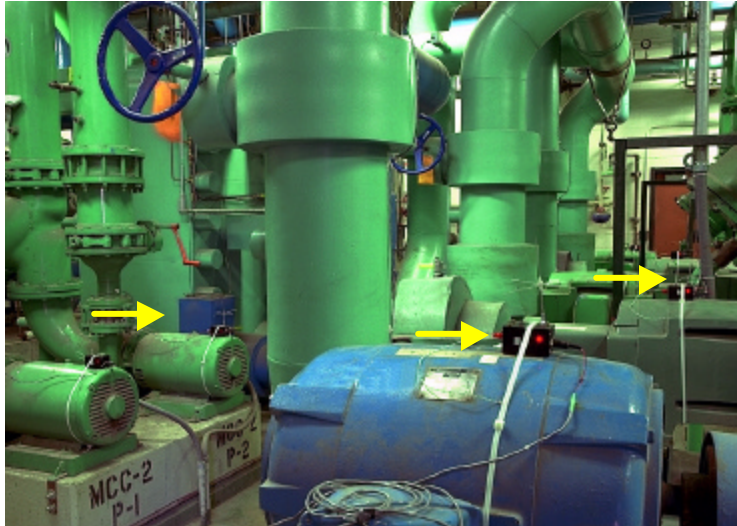
WINS at SUO/SAS Demo, Ft. Benning MOUT Site



- Nodes in building successfully self-organized into a working network
- Successfully detected human footsteps
- Still need work in noise immunity & discrimination



Condition-Based Monitoring & Maintenance Demonstrations



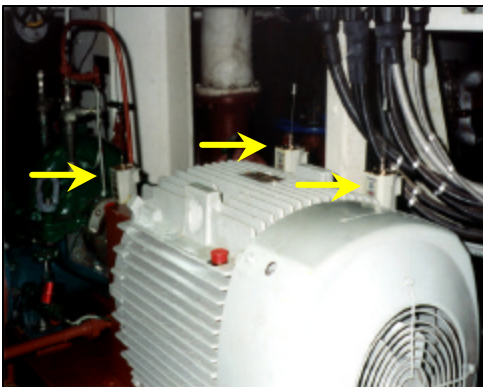
RSC Machine Room

Wireless nodes record temperature and vibration data in mechanical room on cooling pump motors. FFT of vibration data is transmitted to computer display.

wins.rsc.rockwell.com

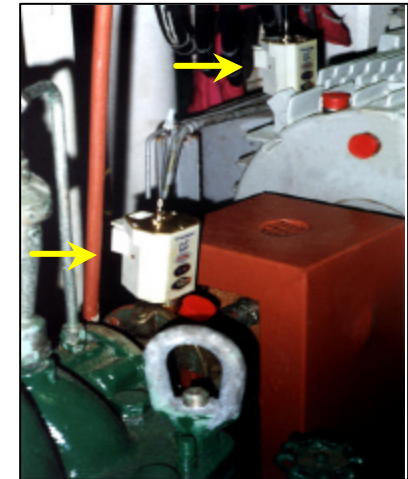


USS Rushmore



Installation at seawater service pump/motor in the Main Engine Room and air compressor motor in the Auxiliary Room.

WINS nodes sense vibration and perform local data processing. Base station node linked to PLC to make data available throughout ship.

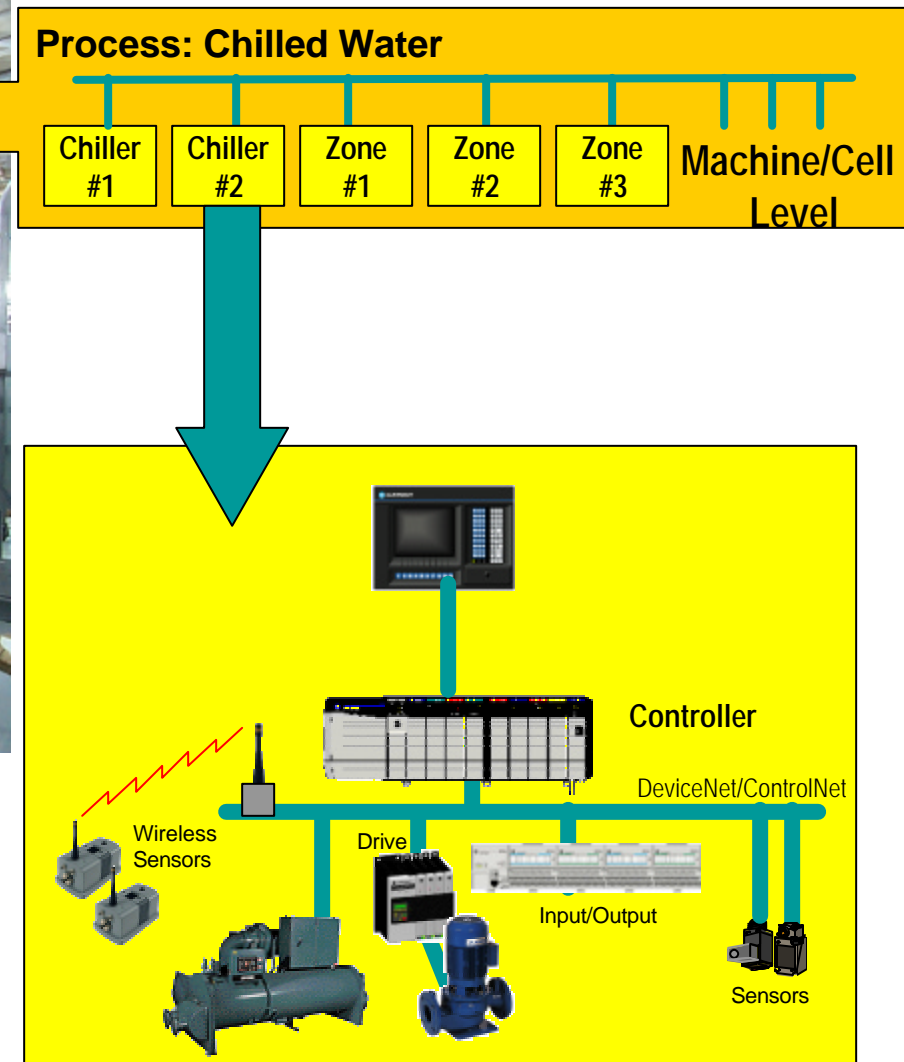


ONR Shipboard Automation



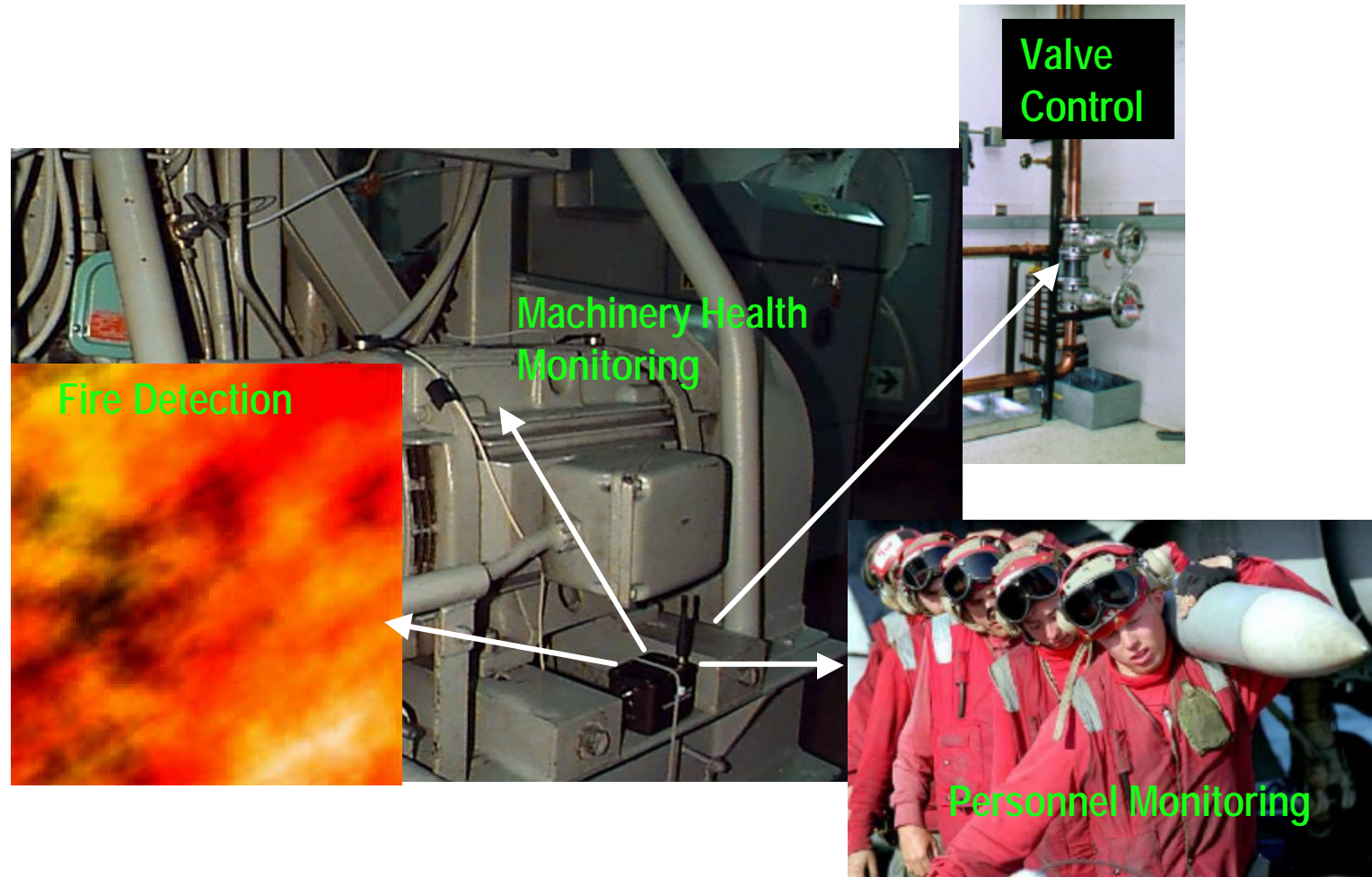
Chilled Water System Test Bed at NSWCCD

Integrated Reconfigurable
Control of Ship Systems

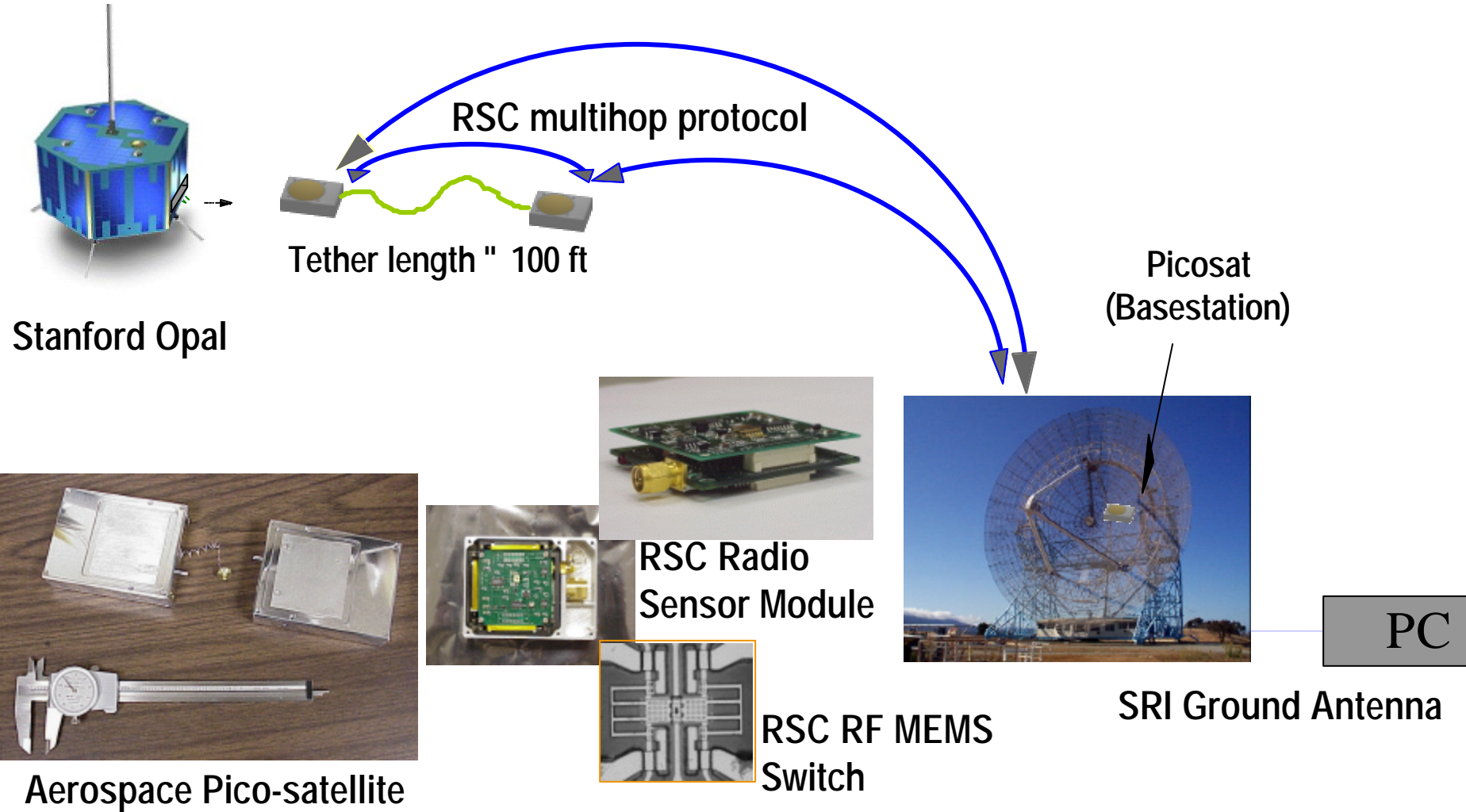


Implemented System

Wireless Nodes - Multipurpose and Reconfigurable



Picosat



Award

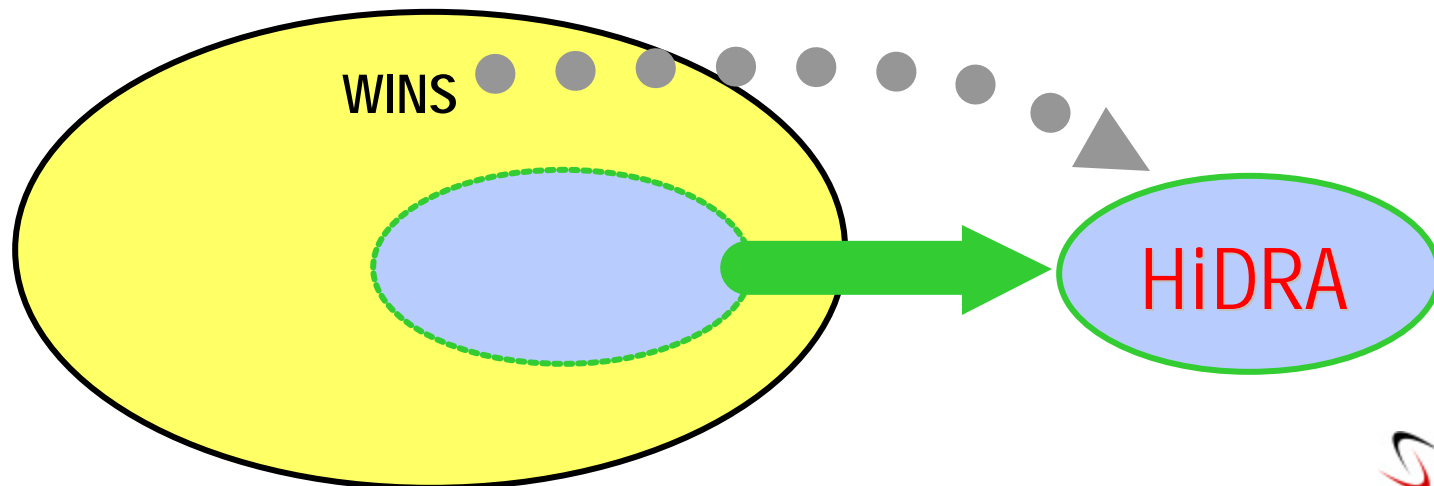


Control Solutions

“...RSC joins a select group of manufacturers. From a field of several thousand product announcements submitted to the *Control Solutions* editors, only three products were chosen...”

WINS & HiDRA

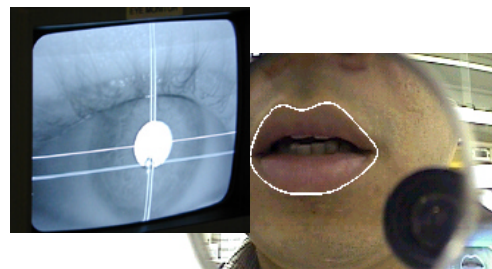
- HiDRA is a Specific Instantiation of RSC WINS Technology
- Zone 5 Networks, inc. is a new company being organized to exploit HiDRA in the industrial automation space
- Zone 5 is presently seeking venture funding
- RSC has licensed WINS technology to Zone 5 for the industrial automation & related commercial markets
- RSC continues R&D in WINS and pursues the military market
- Zone 5 & RSC will collaborate



Integrated Multimodal Systems with Versatile Control for Visualizing & Interacting with Sensor Webs



- Interactive map display
- Wireless Interaction with PDA
- Speech Recognition
 - Multiple concurrent users
 - Standard & body-coupled mikes
 - In-Line Noise Filtering
 - Lip Reading
- Versatile Pointing & Selection
- Point & Speak
- 3D Audio
- Eyetracking
- Look & Speak
- Tetherless Augmented Reality
- Stabilized Displays
- Live Sensor Visualization
- Flexible Architecture based on TCP or UDP



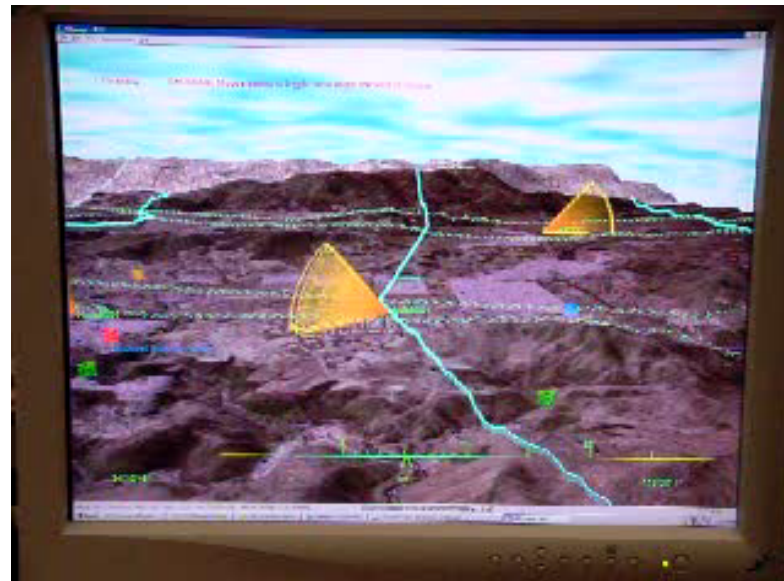
Live Display of Information from Wireless Integrated Networked Sensors



- Live Display of sensed information
- On large display and mobile wearable displays
- Visual and 3-D audio display of sensor-generated alerts
- Multimodal (speech, etc.) control of Sensors



Video



Video

Speech Control of Wireless Integrated Networked Sensors

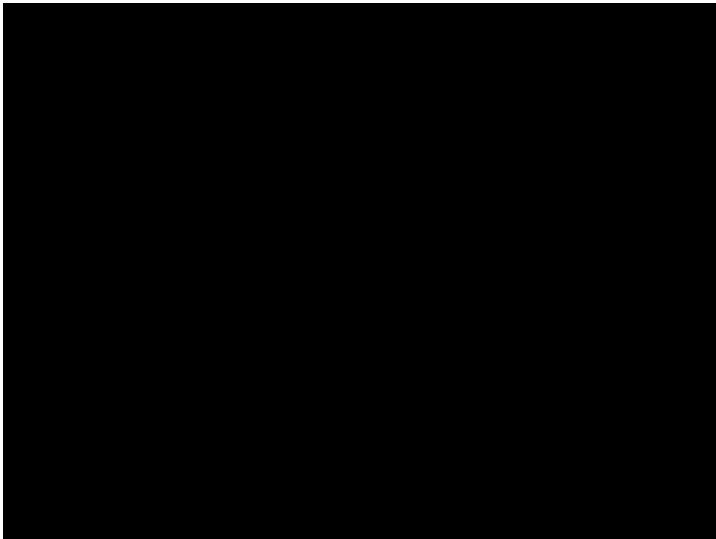


Use Natural Speech
Commands to
Set Thresholds &
Control Sensor
Behavior

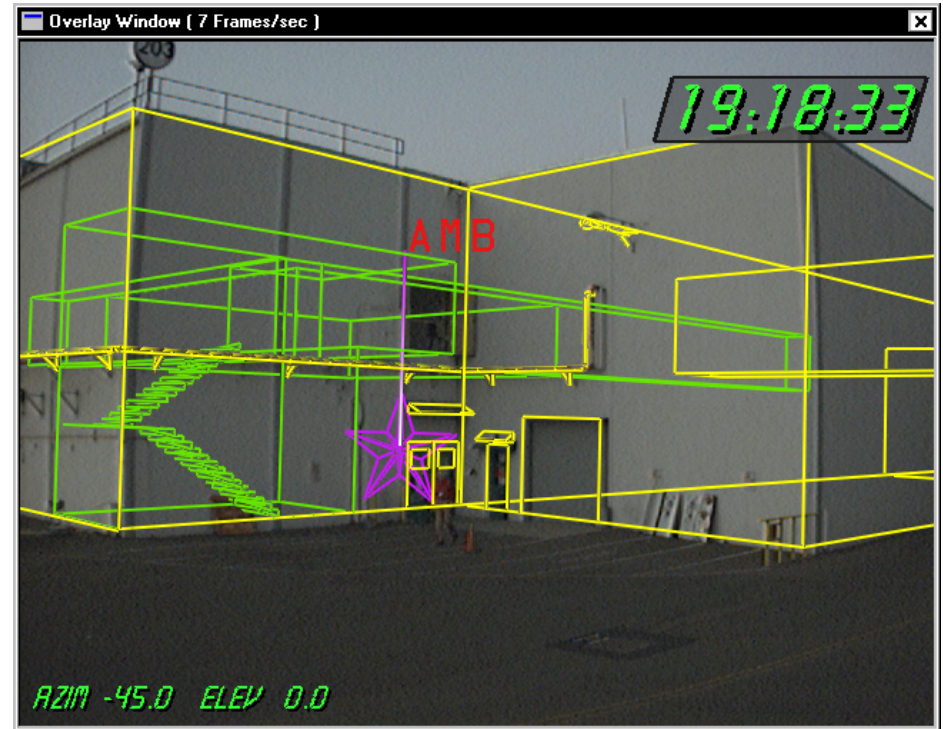
"Set Personnel Sensitivity High"

Video

Wireless Immersive Multimedia Information System (WIMMIS)



Video



RSC Live AR for Boeing FCS Demo 08/01

- Tetherless Augmented Reality
- Overlay & Registration of Computer Models onto Real World
- "X-Ray Vision" into buildings
- Full 3-D Audio
- Visualize & Interact with Sensor Web